MOTOR VEHICLE STEERING COLUMN AND SEAT BELTS WITH A PROTECTIVE DEVICE

CROSS REFERENCE TO RELATED APPLICATIONS

This is a continuation-in-part application of co-pending international application number PCT/DE 98/00694 (WO 98/41422, German Patent DE 19711392 C1) filed March 10, 98.

BACKGROUND OF THE INVENTION

1. Field of the Invention:

It is an object of the present invention to provide the front and/or rear section of vehicle body with an energy-absorbing, vibration-dampening protective device

- to pull the steering wheel out of an area, in which the head, thrown forwards, smashes into it or is propelled backwards by an airbag;
- to damp vibrations and lower pre-tensioning forces, imposed on belted passengers, in association with energy absorption and vibration-dampening,
- to pre-tension the seat belts (safety belts) up to a predetermined length of seat-belt retraction and, when impact energy is great, to preserve the predetermined length of seat-belt retraction and to release pulling wires of the protective device

in any front or rear crash thus ensuring the survival chance either in co-operation with the front airbag or in case of a failure thereof or in operation with airbag.

2. Description of the Related Art:

It is known in the prior art to provide a motor vehicle with front airbags to softly cushion the head or a protective device to pre-tension the seat belts in co-operation therewith while pulling the steering wheel out of a head-injury area in order to avoid head injury. When the

head-injury area is violated in a front crash, the upper part of the body of a front-seated or back-seated passenger belted, more particularly slackly belted or unbelted, is propelled forwards into the steering wheel, windshield, dashboard or backrest of the front seat. Recently, conventional protective devices fail to ensure survival chance in the following cases:

- When crashing into a MB E200 DT on a highway, a 42-year old driver of 5-month old BMW 5, which is strongly yaw-accelerated, suffers quadriplegia.
- In a multi-crash of a 5-year old Ford Mondeo into a barrier and, finally, into a bus near the city of Idstein a 34-year old female driver submarines during which an inflated front airbag, fracturing her front face, forces it into her skull. Falsely deployed side airbags can injure passengers too!
- In a crash of a 3.5-month old BMW 328i into another BMW the head of a 34-year old driver, thrown forwards, totally deforms the steering wheel.
- The operation of airbags and sensors remains, to a surprising extent, unreliable, thus necessitating recall actions of 6,370 SAAB 9000s, 235,000 Volvo S70s, C70s and C70s, 150,000 MBs, 616,000 Opels, 16,500 VWs, 21,000 VWs, 280,000 BMW 3s, 900,000 AUDI 80s, A4s, A6s and A8s, 5,400 Porsche 911 Carreras and 911 Turbos and, recently, 116,000 Volvo S80s.
- Ref. to pp. 178 in German Magazine "AUTO MOTOR und SPORT" issue 12/2002 researchers of Technical University in the city of Aachen found out that over 10 % of airbag systems are defective. Within four years two millions of cars were already recalled due to defective airbag systems. Under these circumstances airbag systems pose to passengers a risk of injuries!

In order to pre-tension the seat belts, operated by a belt pulley driven by an engine, the members of a release device ref. to DE 3536393 A1 are force-locking connected with each

other by a wire (pp. 6/col. 37 to 43), which is activated in the event of deformation of a vehicle member. With the data n = 6000 U/min, radius of belt pulley = 10 mm and t = 20 ms lower than the deployment time of BMW-Frontairbag by 22 ms the formula of seat belt-tension yields a retraction of 20 mm, which is less due to the slip-coefficient of the belt webbing on the belt pulley and due to its elongation and can never meet the requirement for retraction of from 300 to 350 mm.

In order to prevent fire the engine is put out of operation by interrupting the gasoline-supply and/or electric circuit. The release device is out of operation too.

Ref. to WO 90/14253 a front bumper consists of a first part, whereto a first row of rollers is transversely attached, a second part, whereto a second row of rollers is transversely attached, and a first strip member, arranged between both rows of rollers. Both ends of the first strip member are rigidly attached to a pair of movable rollers, about which a second strip member is wounded. Both ends of the second strip member, rigidly attached to seat belts of passengers. In a mid-front crash the deflection of the first rollers between the second rollers causes a lateral movement of both movable rollers in opposite direction during which the second strip member tightens both seat belts to a limited extent. In offset-crashes it does not work.

Despite voluminous form the front bumper is unsuited to absorb small energy when colliding into a barrier during parking. The damage on the device as well as on the front section of the vehicle incurs high repair costs.

Ref. to DE 4106480 A1 a clamping device consists of a front tube, fastened to a longitudinal runner, and a guide, rear tube, which is fastened to the longitudinal runner and the front portion of which is loosely guided by the front tube, to loosely guide a wire. Under the premise, that the distance between both tubes is shorter, when the front portion is

deformed, the wire pre-tensions seat belts of passengers. In real-world front crashes the device is fouled when

- the portion of the longitudinal runner together with the device collapses or
- the front portion with the device is not deformed while the front portion of the other longitudinal runner without device is deformed.

Ref. to a protective device of EP 0234003 A1, designed for a vehicle having mid- or rear-engine, has a pair of longitudinal rods, located in a pair of longitudinal runners, one ends of which and the other ends are fastened to the front portions of both longitudinal runners and to two first wires, which are connected to an intermediate wire in connection with two second wires, connected to the belt retractors. In a mid-front crash the deflection of both front portions of the longitudinal rods causes an elongation of both first wires, which are outwardly deflected upon the contact with guide plates of the longitudinal runners. As a result, both second wires activate the belt retractors to pre-tension the seat belts. Due to lack of vibration-dampening energy absorbers and delimiters the passengers are exposed to large acceleration of those rods, strangulation linked to unlimited deflection and whiplash-related oscillations.

Ref. to DE 3627558 C1 three wires of a protective device, activated by an intrusion of the power plant in a mid-front crash, pull the steering wheel out of the head-injury area and pre-tension all seat belts. Unfortunately, the passengers are subjected to severe/fatal injuries resulting from

- large acceleration, strangulation and whiplash-related oscillations in real-world mid-front crashes or
- failure of the protective device in real-world offset front crashes.

The deficiencies of the features of DE-OS 1655597, DE 3536393 A1, DE 3736949 A1, DE 4106480 A1, WO 85/01709 and WO 90/14253, respectively, are similar to that of EP 0234003 A1 and DE 3627558 C1

In order to resolve the above-mentioned deficiencies of EP 0234003 A1, DE 3627558 C1, WO 85/01709 A1 and DE 3736949 A1 the proprietor AUDI Corp. has invented a protective device, disclosed in DE 3801347 C2, under a trademark "procon-ten", an abbreviation for programmed contraction-tension, shown in **Fig.** 5. In a mid-front crash a rod **201** of the power plant **10** pulls

- a wire **208**, which pre-tensions via pivots **204, 205, 206** seat belts **64** of all passengers in "S_G"-direction and
- a wire **209**, which pulls via two pivots **204, 205** a steering wheel **90** out of the head-injury area in "S_L"-direction during which a collapsible casing **91.1** of the steering column **91**, fastened to a dash panel of the passenger compartment, is compressed.

Unfortunately, the protective device "procon-ten" incurs a series of drawbacks such as:

For years R&D work has been focused on

- developing compact as well subcompact cars suitable for daily driving to workplace, meeting with customers, resolving the problems of increasing traffic congestion, easily finding a parking lot and lowering the fuel consumption to under 4 l/100 km and
- improving the passenger protection to pass increasingly difficult EU and US-crash tests.

A compact car, such as MB (Mercedes Benz) A-Class ® with 3.58 x 1.56 x 1.72 m, has an extremely short front section, for which the device "procon-ten" is unsuited. In order to enhance survival chance and the energy-absorbing property of longitudinal runners in a mid-front crash the power plant **10**, sliding down along the stiff sliding surface (scuttle) **55**, is displaced from the engine compartment to underneath the passenger compartment while rear bearings **22**, serving as sites of predetermined fracture, are broken, as exemplified in US Pat.

No. 5,492,193 and shown in **Figs.** 2 and 3. In an offset front crash or in a major mid-front crash this embodiment fails due to fouling the condition that both rear bearings must be broken simultaneously. This and other shortcomings are resolved by features of separation of the power-plant from the front section of the vehicle body and/or by enhanced energy absorption of longitudinal runners in front- or rear crashes, disclosed in DE 19636167 C1, CA 2,236,816 and US-pending patent.

An Institute of Vehicle Safety, a Department of GDV (Association of German Insurers), in Munich has conducted a research on front crashes, classified into four front crash types one of which, the mid-front crash type, shows a low percentage just 19.3 % regarding fatal injuries.

The upper part of body as well as the head are subjected to strong oscillation due to lack of undamped vibration in a front- or rear crash. In the crash tests, carried out by the Institute of Vehicle Safety in co-operation with Technical University in Graz, Austria, to idealize a real-world rear crash, the torso is propelled out of the seat backrest after a lapse of 40 ms (milliseconds) while the initial position of the head remains unchanged. After a lapse of 100 ms the head is accelerated backwards. After a lapse of 130 ms the head comes into contact with the head rest. The pitch acceleration reaches the maximum. A rebound (repetition of forward motion) of the upper part of body occurs within 200 ms. Despite low speed at 8.5 km/h and low acceleration at 2.5 g in the crashtests of nine different vehicle seats the upper part of body always oscillates. One out of 22 volunteers suffers minor cervical injury, lasting for two days, and a few minor pain, lasting for one to two days.

Due to poor energy-absorption of the rod 201 of the power-plant, far less than that of both deformable longitudinal runners having a peak acceleration of 60 m/s^2, disclosed in DE 3826958 A1, and due to great remaining impact energy, when crashing at high speed into the very stiff column of a highway, the power plant intrudes into the passenger compartment and

the seat belts, strongly pulled by the wire **208**, strangulate all restrained passengers, particularly, a fetus of pregnant female passenger.

The rod **201** has to carry out five operations to limit the backward movement of the power plant, to absorb impact energy, to serve as the third bearing of the power plant, to adjust the wire and to convert the movement of the power plant into a movement of both wires. The failure of the device is due to the controversy of the different operations.

Ref. to DE 4224489 A1, whose features are found in AUDI A8 as well as A2, and DE 3826958 A1 a deformable longitudinal runner with a length of "L_E", shown in **Fig.** 10, is subdivided into "n+1" longitudinal members "$Z_1, Z_2, .. , Z_a, .. , Z_b, .. , Z_c, .. , Z_d, .. , Z_n, Z_{n+1}$". The longitudinal member "Z_{n+1}", having the largest stiffness, is the rear portion of the longitudinal runner, facing the passenger compartment.

Furthermore, DE 19615985 C1 (pending CA 2,249,667) and DE 19636167 C1 (CA 2,236,816 and US-pending patent) teach the stiffness of the longitudinal runner can be increased by additional elements integrating therein. Controllable deformation behaviour is accomplished by inequal stiffness of juxtaposed longitudinal members, under load, having different peak stresses. However, they may have peak stresses at the same level as long as their longitudinal members, for example, "Z_2" and "Z_{10}" are not in juxtaposition. The transient times to the yield value (fracture stress) are variable, hence, determinable. To resolve the problem of buckling of conventional longitudinal runner under great load and to achieve the highest efficiency of the energy absorption the deformable longitudinal runner, guided by the piston rod, is controllably folded, buckled and reamed by a cone- or torus-shaped hub **5.3** of piston head **5.1a**, shown in **Fig.** 6.

SUMMARY OF THE INVENTION

Accordingly, the principle object of the present invention is provide for a motor vehicle a protective device, comprising a pair of independently operating piston devices, arranged in the front and/or rear section of vehicle body, wires, pivots (pivotal rollers), and vibration-dampening, energy-absorbing delimiters in order to pre-tension the seat belts of all passengers and absorb the pre-tensioning forces to a predetermined length of seat-belt retraction, lower the belt forces, resulting from mass forces of the forward motion movement of the belted passengers, dampen whiplash-related oscillations of the belted passengers and pull the steering wheel out of a head-injury area in real-world front or rear crashes.

A second object of the present invention resides in the independently operating piston device having a cone- or torus-shaped hub which folds, buckles and reams the deformable longitudinal runner, being loosely guided by the piston rod, in order to gradually absorb impact energy and to achieve the highest efficiency of the energy absorption.

A third object of the present invention resides in a cost-, space-saving construction of different protective devices, each of which, provided with means to compensate manufacturing and assembly tolerances, can be installed in any motor vehicle, as exemplified in the compact car MB A, shown in **Figs.** 2 and 3. A car manufacturer, having many vehicle classes (models) on the sales program, can equip them with one to two protective devices, whose wires **60, 61, 62** have a few different wire lengths and whose piston rods **5a to 5d** have a few different wire lengths. In compliance with cost-, space-saving arrangement the following pair of piston rods **5, 5a to 5d, 5c1** can be arranged in the front and rear section of vehicle body of several vehicle models pursuant to the Claims 1 to 3 and 26 to 28 :

- Ref. to **Figs.** 1, 6 and 11 a guide member **52**, to accommodate a wire and a delimiter and deform an additional energy absorber **1**, is fastened to the rear portion of each piston rod **5**, which is arranged in the longitudinal runner **30** and guided by a bearing box **30.7, 30.7a**, rigidly attached thereto and/or to the torque box **31**.

- Ref. to **Figs.** 2 and 4 the front portion of each piston rod **5c**, arranged sideward to the longitudinal runner **30**, is bolted to the front portion of longitudinal runner **30**, the mid-portion is loosely guided by a bearing **58c** of reinforced dash panel **55** and a guide sleeve (member) **52a**, to accommodate two wires, is fastened to the rear portion.
- Ref. to **Figs.** 3, 3a and 4 the front portion of each piston rod **5c1**, arranged sideward to the longitudinal runner **30**, is bolted to the front portion of longitudinal runner **30**, the mid-portion is loosely guided by a bearing **58c1** of torque box **31** and a guide sleeve **52a**, to accommodate two wires, is fastened to the rear portion.
- Ref. to **Fig.** 7 the front portion of each piston rod **5d**, arranged lower to the longitudinal runner **30**, is bolted to the front portion of longitudinal runner **30**, the mid-portion is loosely guided by a bearing **58d** of torque box **31** and a guide sleeve **52a**, to accommodate two wires, is fastened to the rear portion.
- Ref. to **Fig.** 9 the front portion of each piston rod **5a**, arranged upper to the longitudinal runner **30**, is bolted to the front portion of longitudinal runner **30**, the mid-portion is loosely guided by a bearing **58a** of torque box **31** and a guide sleeve **52a**, to accommodate two wires, is fastened to the rear portion.
- Ref. to **Fig.** 10 the front portion of each piston rod **5b**, arranged in the longitudinal runner **30**, is bolted to the front portion of longitudinal runner **30**, the mid-portion is loosely guided by a bearing **58b**, which is a hole in the torque box **31**, and a guide sleeve **52a**, to accommodate two wires, is fastened to the rear portion.

Shown in **Fig.** 3a, the bearing **58a to 58d, 58c1** is provided with a soundproofing bush **58.1** to isolate noise and enhance the movement of the piston rod therein when being displaced together with the longitudinal runner **30**. Accordingly, piston rods **5c, 5c1, 5d, 5b** are provided with soundproofing bushes, like **54.1**, shown in **Fig.** 9, at the respective attachment

points. To save assembly time the hole of piston rod **5b** is pre-assembled with rubber sleeve (not drawn).

The profile of piston rods **5a to 5d, 5c1, 5e1 to 5e4** is arbitrary, however preferably, round or square due to low manufacturing costs.

Usually, manufacturing tolerances and indeterminate (large) assembly tolerances result in a play which must be compensated by repositioning the wire to the piston rod, to the delimiter and/or to the clamping member of the delimiter and/or the piston rod to the longitudinal runner. This requirement for an appropriate position of the wire is met by distributing the following adjusting holes along the following members of the protective device:

- adjusting holes "H_1, H_2, .. , H_n" along piston rod **5d (Fig. 7)**,
- adjusting holes "K_1, K_2, .. , K_n" along piston rod **5a, 5b, 5d (Figs. 7, 9, 10)**,
- adjusting holes "L_1, L_2, .. , L_n" and "N_1, N_2, .. , N_n" along delimiter **51** with site of predetermined fracture "b" **(Fig. 11)**,
- adjusting holes "N_1, N_2, .. , N_n" along delimiter **51a, 51c, 51d, 51e** with site of predetermined fracture "b" **(Figs. 8, 9 and 19 to 21)** and/or
- adjusting holes "M_1, M_2, .. , M_n" along tube **71.1** or clamping member **82, 82a, 82b (Figs. 12 to 16)**.

Alternatively, a spacer **60.6** with open profile and length of "g_1" is clamped onto a pre-wire **60.1e**, preferably, in front of the blocking ring **60.7** to correct the distance of "g" between the blocking ring **60.7** and support plate **60.8**, fixed to the side rail **34**, shown in **Fig. 21**. The process of clamping is illustrated by an arrow. The adjusting work can be done elsewhere upon allocation of a number of spacers **60.6** with different lengths "g_1, g_2, .. , g_m, g_n" (not shown).

In a time-, cost-saving decision an assembly worker at assembly line can compensate a play by occupying, for example, an appropriate hole "L_3" **(Fig. 11)** for fastener **51.2** of delimiter

51 instead of the designed hole "L_1" and/or by clamping a spacer 60.6 with open profile and length of "g_1" to the pre-wire of wire **61, 62**.

A fourth object of the present invention facilitates the protective device to co-operate with a separation of the power plant ref. to DE 19636167 C1 (CA 2,236,816 and US-pending patent) and with additional energy absorbers ref. to DE 19615985 C1 (pending CA 2,249,667), such as energy absorbers **1**, shown in **Figs.** 1, 6 and 11, in order ensure and enhance survival chance and, in particular, resolve the crash incompatibility issue, in which a light car, for example, a subcompact or compact car, is front-end hit by a utility vehicle, for example, a pickup, truck or SUV. As reported in IIHS Vol. 34, No. 9, Oct. 30, 1999, two-vehicle collisions between cars and utility vehicles in USA account for about 15 percent of all car occupant deaths.

In surmounting the foregoing shortcomings of conventional protective devices and of the failure in offset front crashes or major accidents all the objects ensure the operation of the protective device as well as survival chance in real-world front crashes, illustrated in **Figs.** 1 to 3 and 6 to 10, where

- in an offset front crash, when "F > $\underline{F}$", the piston rod **5** moves (backwards) along the y2-axis or, when "$\underline{F}$ > F", the other piston rod **5** moves along the $\underline{y2}$-axis, or
- in a mid-front crash, when "F = $\underline{F}$", both piston rods **5** move along the y2- and $\underline{y2}$-axis.

During which impact energy is absorbed by at least one longitudinal runner **30** and by at least two pairs of vibration-dampening, energy-absorbing delimiters **70, 80, 80a to 80e** with site of predetermined fracture "b", shown in **Figs.** 12 to 21, and, optionally, by at least one deformable element **1**, shown in **Figs.** 1 to 6.%

Obviously, the operation to pre-tension seat belts in direction "S_0" has to be separated from that to retract the steering wheel out of the head-injury area independent of direction "S_1" and "S_2". The retraction must be limited by at least one delimiter **51, 51a** with site of

predetermined fracture "b" (**Figs.** 8, 9 and 11). Both features are extended by the following features. Each vibration-dampening, energy-absorbing delimiter **70, 80, 80a to 80e**, shown in **Figs.** 1, 12 to 21, has a multi-purpose:

- to perform work of deformation and of friction, thus absorbing (dissipate) impact energy, lowering the pre-tensioning force of seat belts, by fracturing the sites of predetermined fracture "b" in excess of a predetermined value, and damping whiplash-related oscillations, thereto the heads are exposed,
- to limit (restrict) the retraction-length of seat belts in order to prevent strangulation and
- to preserve lengths of retracted seat belts and the clamping force of the clamping member on the retaining member by way of engagement of retaining assembly, consisting of
  * retaining notch of tube **71.1** and retaining plate **71.3**, pivotally attached to both plates **71.4** and biased by spring **71.5**, shown in **Fig.** 12, or
  * a pair of retaining apertures of expanding clamping member **82a** and two-side retaining strut **81.2a** of retaining member **81a**, shown in **Figs.** 14 and 15, or
  * a retaining collar **82.1b** of contracting clamping member **82b** and retaining notch of retaining member **81b**, shown in **Figs.** 16 to 18.

Clamping (spring) force of the clamping member on the retaining member depends on the material, length, denoted by "l", longitudinally variable width of gap, denoted by "s", shape of the delimiter itself and spring rate of the clamping member, which expands or contracts, during its forced movement along the cone-shaped portion of the retaining member.

Applying the same parameters on the design of the delimiter and the cone-shaped portion of the retaining member, the clamping force of the clamping cylinder-shaped member **82** with diameter of "d_0" is less than that of the clamping cone-shaped member **82a**. For the purpose of ideal contact with each other the portion **81.3a to 81.3e** of retaining member **81a to 81e**

and clamping member **82a to 82e** have the same conical shape, determined by the formula "$(D_2-D_1)/L = (d_2-d_1)/l$", shown in **Figs.** 14 to 21. Owing to these features

- the expansion or contraction of the clamping member increases the clamping force and
- work of deformation and of friction is accomplished when the clamping member, whose gap is loosely guided by the part of the mating retaining member, moves along the retaining member.

Due to longitudinally contracting the circumference of clamping member with diameter "D_2" and "D_1" to an amount of, for example, 0.5 mm the clamping force of the delimiter **80a, 80c** is increased accordingly.

Each delimiter **80, 80a to 80e** under load of pre-clamping force can be pre-assembled by

- expanding the clamping member **82, 82a, 82c** with gap, arranged on the retaining member **81, 81a, 81c**, or
- contracting the clamping member **82b, 82d** with gap, arranged in the retaining member **81b, 81d**.

Owing to big friction coefficient, large contact area of clamping member with retaining member and wide expansion or contraction the clamping force is strong enough to pre-tension and retain the seat belts. A test can determine whether the cheapest delimiter **80e** without retaining and blocking parts, shown in **Fig.** 21, works. It consists of

- a retaining member **81e** representing any one of members **81, 81a to 81d** and
- clamping member **82e** representing any one of members **82, 82a to 82d** without retaining and blocking parts, however, with alien-blocking parts **60.6 to 60.8**.

To avoid noises the cone-shaped portion of retaining member **81, 81a to 81e** is surrounded by a soundproofing material **83**, shown in **Fig.** 15. The work of friction depends on clamping force, surface property of both members on contact and friction coefficient. The work of

deformation, friction is achieved during the deformation of clamping member, pulled by the wire **60**, moved along the retaining member, similar to spring **72** and shock absorber **73**.

BRIEF DESCRIPTION OF THE DRAWINGS

A number of embodiments, other advantages and features of the present invention will be described in the accompanying drawings with reference to the xyz global coordinate system:

Fig. 1 is a schematic view of a vehicle frame, a power plant **10**, steering wheel **90**, steering column **91** and a pair of deformable elements **1**, loosely guided by guide members **52**, and a 1st embodiment of the protective device, having a pair of independently operating piston rods **5** with piston heads **5.1**, guided by bearing boxes **30.7**, which are arranged to a pair of longitudinal runners and/or a torque box **31**, wires **60 to 62**, energy-absorbing delimiters **51**, pivots **40 to 49** and two pairs of energy-absorbing, vibration-dampening delimiters **70** in xy-plane.

Fig. 2 is a longitudinal cross section of a transversally-built power plant of MB A being displaced ref. to US Pat. No. 5,492,193 and a schematic view of a 3rd embodiment of the protective device in a mid-front crash.

Fig. 3 is a longitudinal cross section of a transversally-built power plant of MB A being displaced ref. to US Pat. No. 5,492,193 and a schematic view of a 4th embodiment of the protective device in a mid-front crash.

Fig. 3a is a partially enlarged cross-sectional view of a bearing **58c** with a soundproofing bush **58.1** to guide each piston rod **5c1** of the protective device, shown in **Fig.** 3.

Fig. 4 is a perspective view of the longitudinal runner **30**, whose longitudinal member "Z_c", reinforced by an additional element **3c**, accommodates the front portion of the piston rod, shown in **Figs.** 2 and 3.

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Figs. 2 and 3 illustrate a longitudinal cross section of a transversally-built power plant of MB A being displaced ref. to US Pat. No. 5,492,193 and a 3rd and a 4th embodiment of the protective device in a mid-front crash.

Fig. 3a is a partially enlarged cross-sectional view of a bearing **58c** with a soundproofing bush **58.1** to guide each piston rod **5c1** of the protective device, shown in **Fig.** 3.

Fig. 4 is a perspective view of the longitudinal runner **30**, whose longitudinal member "Z_c", reinforced by an additional element **3c**, accommodates the front portion of the piston rod, shown in **Figs.** 2 and 3.

Fig. 5 is a perspective view of an AUDI protective device "procon-ten" ref. to DE 3801347 C2.

Fig. 6 is a schematic view of a vehicle frame, a power plant **10** and a pair of deformable elements **1**, loosely guided by guide members **52**, and a 2nd embodiment of the protective device, having a pair of independently operating piston rods **5** with cone- or torus-shaped hubs **5.3** and piston heads **5.1a**, guided by bearing boxes **30.7a**, arranged to a pair of longitudinal runners and/or a torque box **31**, and delimiters.

Fig. 7 is a perspective view of a longitudinal runner **30**, whose longitudinal member "Z_d", reinforced by an additional element **3d**, accommodates a piston rod **5d** of a 5th embodiment of the protective device.

Fig. 8 is a cross-sectional view of a 6th embodiment of the protective device, along the line II-II of **Fig.** 9, having a delimiter **51a** and a spacer **51.6a** with open profile and length of "f_1" which is in process to be clamped onto a wire **61** to correct the distance of "f" between the blocking ring **51.4a** and support plate **51.5a**.

Fig. 9 is a schematic perspective view of a half of the 6th embodiment of the protective device with piston rod **5a**, wires **60, 61**, guide sleeve **52a,** pivots **44a, 47a, 48** and the delimiter **51a**.

Fig. 10 is a schematic perspective view of the longitudinal runner **30**, subdivided into "n+1" longitudinal members one "Z_b" of which is reinforced by an additional element **3b** to accommodate a piston rod **5b** of a 7th embodiment of the protective device.

Fig. 11 is a cross-sectional view of the 1st embodiment of the protective device along the line I-I of **Fig.** 1.

Fig. 12 is a schematic perspective view of the delimiter **70** having a delimiting unit **71**.

Fig. 13 is a schematic perspective view of a 2nd embodiment of the energy-absorbing, vibration-dampening delimiter **80**.

Fig. 14 is a schematic perspective view of a 3rd embodiment of the energy-absorbing, vibration-dampening delimiter **80a**.

Fig. 15 is a cross-sectional view of a clamping member **82a** of the delimiter **80a** whose movement, guided by a longitudinal strut **81.1a** of retaining member **81a** and/or a retaining strut **81.2a**, is blocked by a pair of retaining apertures in engagement with the retaining strut **81.2a** along the line III-III of **Fig.** 14.

Fig. 16 is a schematic perspective view of a 4th embodiment of the energy-absorbing, vibration-dampening delimiter **80b**.

Figs. 17 and 18 illustrate a cross-sectional view of a clamping member **82b** of the delimiter **80b** whose movement, guided by a guide pin **82.2b**, is blocked by a retaining collar **82.1b** in engagement with a retaining notch of retaining member **81b** along the line IV-IV of **Fig.** 16.

Fig. 19 is a schematic perspective view of a 5th embodiment of the energy-absorbing, vibration-dampening delimiter **80c**.

Fig. 20 is a schematic perspective view of a 6th embodiment of the energy-absorbing, vibration-dampening delimiter **80d**.

Fig. 21 is a schematic perspective view of a 7th embodiment of the energy-absorbing, vibration-dampening delimiter **80e**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The right-hand drive vehicle is represented by the steering wheel **90**, shown in **Figs.** 1 and 5. However, all features are suited for right-hand drive vehicles as well as for left-hand drive vehicles.

The 2nd embodiment of the protective device, shown in **Fig.** 6, differs from the 1st embodiment, shown in **Fig.** 1, in the piston rods **5.1a**, provided with cone- or torus-shaped hubs **5.3** which avoid an extremely outward deflection of longitudinal runners during

deforming, reaming and folding the longitudinal members in longitudinal direction to substantially dissipate great impact energy.

The end portion of each piston rod **5**, guided by bearing box **30.7, 30.7a**, is fastened to a guide member **52** of deformable element **1**, shown in **Figs.** 1, 6 and 11, which has a web with a hole, serving as pivot **47** to pivotally move and deflect the wire **60**. The wire **60**, further wound about the pivots **48, 49**, has both ends, attached to at least one pair of delimiters **70, 80, 80a to 80e** in connection with all seat belts of the motor vehicle.

Each guide member **52** accommodates a delimiter **51**, one of the adjusting holes of which is occupied by one end of wire **61, 62**. Onto the other ends wire holders **61.1, 61.2** are clamped. Both wires are wound about the respective pivots **42, 43** and **45, 46**. Threaded stud **41.1**, accommodating both wire holders, has a threaded end projection onto which a nut **41.2** is screwed to secure them.

Upon large deflection of guide member **52** in an offset front crash the seat belts **64** of belted passengers are pre-tensioned up to a predetermined length of seat-belt retraction, vibration is dampened, energy is absorbed by deforming the longitudinal runner **30**, deformable element **1** and the delimiters **70, 80, 80a to 80e, 51, 51a** and the movement of blocking pin **51.4** is blocked by support plate **51.5** thus ending up in fracture of site of predetermined fracture "b" and in further pulling of the steering wheel **90** until it comes into contact with the dashboard. As a result, the site of predetermined fracture "b" of the delimiter **51a** (**Fig.** 8) is broken and the wire **61, 62** is released. Alternatively, only one single pair of delimiters **51** is used. In that case the site of predetermined fracture "b" has to be redesigned between the hole "L_1" and the guide member **52** (**Fig.** 11). Car Corps. have an option for a single or multi-energy absorption.

Due to great impact energy the wire **60** is released too and the predetermined length of seat-belt retraction and the clamping force are conserved, as outlined hereinafter.

In the 1st embodiment the delimiter **70,** shown in **Figs.** 1 and 12, comprises a spring **72,** shock absorber **73** and a delimiting unit **71,** consisting of a tube **71.1** and support member **71.2** with plate **71.3,** which, biased by spring **71.5,** comes in engagement with a notch of the tube, being moved by tension force of wire **60,** to limit the retraction-length of seat belts. The non-recurring delimiter **70** is too expensive. Car Corps. are interested more in cost-, space saving embodiments, which are described hereinafter:

In the 3rd to 7th embodiments without costly bearing boxes **30.7, 30.7a,** shown in **Figs.** 2, 3, 7, 9 and 10, a pair of piston rods **5a to 5d, 5c1** is arranged in or to the longitudinal runners **30.** The piston rod provided with bush such as **54.1** is in force-locking connection with the reinforced longitudinal member by way of riveting or welding or a fastener, consisting of bolt **54** and nut **54.2,** shown in **Fig.** 9. Costs are further saved by multi-use of the fastener **52.1** to fasten the wire holder **61.1a** of wire **61** to guide sleeve **52a,** shown in **Figs.** 9 and 10, and the guide sleeve **52a** to piston rod **5a, 5b** as well as by multi-use of the guide sleeve **52a** to retain those wires and to pivotally move and deflect the wire **60.**

Each retaining member of energy-absorbing, vibration-dampening delimiter **70, 80, 80a to 80e,** shown in **Figs.** 1, 12 to 21, has attachment points for the purpose of force-locking connection with any stiff vehicle member like side rail **34,** shown in **Fig.** 21.

Each member **71.1, 82, 82a to 82c,** movable by tension force of wire **60,** is provided with site of predetermined fracture "b" to limit the retraction-length of seat belts. Alternatively, the delimiters **80d, 80e** in co-operation with delimiters **51a to 51e,** each having site of predetermined fracture "b", are put into use.

In the 2nd and 3rd embodiment the delimiter **80, 80a,** shown in **Figs.** 13 to 15, comprises an expanding clamping member **82, 82a** and a retaining member **81, 81a.** The work of deformation and friction is increased when the mating members, being in contact with each other, are cone-shaped. A gap, denoted by "s", has influence on the spring rate or clamping

force and the engagement of both members with each other. Owing to the guide assembly, consisting of the gap and the strut **81.1, 81.1a**, the clamping member **82, 82a**, loosely guided by the strut, moves along the retaining member **81, 81a**. To maximize the clamping force of clamping member **82a** moving along the retaining member **81a**, a longitudinal gap "S_A" (not drawn) must be defined by the magnitude of longitudinal gap "$s_a > 0$" which may neither be too small nor too big between the gap and strut **81.1a** as well as between the gap and two-side retaining strut **81.2a** in longitudinal direction. After projection through holes of clamping member **82a** and fork-shaped wire holder **60.2** of belt wire **60.1** of seat belts **64**, the blocking pin **60.3** is secured by two securing parts **60.4**. After engagement of the retaining assembly, consisting of a pair of apertures and the two-side retaining strut, further movement of the clamping member **82a** is blocked upon the contact of blocking pin **60.3** with the surface of retaining member **81a** because its clearance of "s_2" is smaller than the clearance of "s_1" (**Fig.** 15). Site of predetermined fracture "b" is fractured by great impact energy to prevent strangulation of belted passengers and to limit the pre-tensioning force.

In the 4th embodiment the delimiter **80b**, shown in **Figs.** 16 to 18, comprises a contracting clamping member **82b** and a retaining member **81b**. After projection through holes of clamping member **82b**, wire holder **60.2a** of belt wire **60.1** and a pair of guide sleeves **60.5a**, end projections of the blocking pin **60.3a** are secured by two securing parts **60.4a**. Owing to a guide assembly, consisting of a guide pin **82.2b** and a gap, the clamping member **82b**, loosely guided by the guide pin, moves along the retaining member **81b**. To maximize the clamping force of clamping member **82b** moving along the retaining member **81b**, a longitudinal gap "S_B" (not drawn) must be defined by the magnitude of longitudinal gap "$s_b > 0$" which may neither be too small nor too big between the gap and guide pin **82.2b** in longitudinal direction.

A cone-shaped chamfer, denoted by "a", assists the process of engagement of a retaining assembly, consisting of retaining collar **82.1b** of clamping member **82b** and a retaining notch of retaining member **81b**. After the engagement of retaining collar **82.1b** with the retaining notch within a clearance of "s_3", further movement of the clamping member **82b** is blocked upon the contact of the pair of guide sleeves **60.5a** of blocking pin **60.3a** with a pair of open notches of retaining member (**Figs.** 17 and 18). Site of predetermined fracture "b" is fractured by great impact energy to prevent strangulation of belted passengers and to limit the pre-tensioning force.

In the 5th embodiment the delimiter **80c**, shown in **Fig.** 19, comprises an expanding clamping member **82c** without site of predetermined fracture, a retaining member **81c**, retaining assembly, consisting of a pair of retaining apertures and two-side retaining strut **81.2c** of strut **81.1c**, and delimiter **51c** with site of predetermined fracture "b". After projection through holes of clamping member **82c**, fork-shaped wire holder **60.2c** of pre-wire **60.1c** and two guide sleeves **60.5a**, the blocking pin **60.3c** (similar to **60.3**, hence not drawn) is secured by two securing parts **60.4a**. The process to preserve the clamping force is similar to that of the 3rd embodiment.

In the 6th embodiment the delimiter **80d**, shown in **Fig.** 20, comprises a contracting clamping member **82d** without site of predetermined fracture, a retaining member **81d**, retaining assembly, consisting of a retaining notch and retaining collar **82.1d** of clamping member **82d**, and delimiter **51d** with site of predetermined fracture "b". After projection through holes of clamping member **82d**, fork-shaped wire holder **60.2d** of pre-wire **60.1d** and two guide sleeves **60.5a**, the blocking pin **60.3d** (not drawn, similar to **60.3**) is secured by two securing parts **60.4a**. The process to preserve the clamping force is similar to that of the 4th embodiment.

In the 7th embodiment the most economical delimiter **80e** without retaining and blocking parts, shown in **Fig.** 21, comprises an expanding or contracting clamping member **82e** without site of predetermined fracture, a retaining member **81e** and delimiter **51e** with site of predetermined fracture "b".

As above-mentioned, the distance between blocking ring **60.7** and support plate **60.8** is adjusted by spacer **60.6** and the process to preserve the clamping force is similar to that of the previous embodiments.

In order to formulate in single terminology for Claims a generalized definition for the proper term is presented:

Definition:	**Proper Term:**
"guide assembly"	guide member **(81.1, 81.1a, 82.2b)** & guided member, such as gap etc.
"retaining assembly"	key **(81.2a, 82.1b)** & receptacle, such as a pair of retaining apertures, retaining notch etc.
"blocking assembly"	blocking member **(60.3, 60.3a)** & contacted member, such as surface of retaining member, a pair of open notches etc.

Although the present invention has been described and illustrated in detail, it is clearly understood that the terminology used is intended to describe rather than limit. Many more objects, embodiments, features and variations of the present invention are possible in light of the above-mentioned teachings. Therefore, within the spirit and scope of the appended claims, the present invention may be practised otherwise than as specifically described and illustrated.